

Perceptual and Motor Skills, 1966, 23, Copy No. 1 2 © Southern Universities Press 1966

HUMAN PERFORMANCE AND BASAL SKIN CONDUCTANCE IN
A VIGILANCE-TYPE TASK WITH AND WITHOUT
KNOWLEDGE OF RESULTS¹

JOHN COULES AND DONALD L. AVERY

Decision Sciences Laboratory, Electronic Systems Division, Bedford, Mass.

Summary.—This study showed no trends between reaction time and inter-stimulus intervals and reaction time and time blocks under knowledge of results or no knowledge of results. An $ABC \times S$ variance design of reaction time scores showed only knowledge of results by Ss was statistically reliable. The source of this variance was attributed to sex differences. Results showed that under knowledge of results fast mean reaction time (males) was associated with high skin conductance. For females slow mean reaction time was associated with low conductance. Under the no knowledge of results condition, females showed slower mean reaction time than males. Their conductance scores showed significantly greater variability without knowledge of results than under the knowledge condition. Males under no knowledge show mean conductance scores as high as those under knowledge of results. However, their mean reaction time scores under the no knowledge condition was significantly lower than under knowledge of results. It was concluded that males, contrasted with females, respond differentially to knowledge and no knowledge of results in simple reaction time studies. As males show high conductance and females high variability in conductance under no knowledge of results, an inhibition-reinforcement theory for vigilance tasks appears inadequate.

Based on a series of experiments on reaction time in vigilance-type tasks McCormack (1962) postulates an inhibition-motivation theory. He follows Mackworth's approach (1950) in stating that inhibition develops in the absence of reinforcement (no knowledge of results) leading to poor performance. On the other hand, knowledge of results acts as a reinforcer resulting in fast reaction time. By this formulation a variety of experimental findings in reaction time and signal detection studies are integrated. However, there is some physiological evidence (Ross, *et al.*, 1959) as well as retrospective reports (Bakan, 1963) that may question some aspects of this theory, particularly, the broad and extensive use of the concept of inhibition.

It is generally accepted that knowledge of results provides high motivation (reinforcement) and information content to the observer (Wiener, 1962; Jerison & Pickett, 1963). Obviously, no knowledge of results provides no objective information concerning one's performance. The question is raised whether no knowledge of results means low motivation or inhibition as used by McCor-

¹This is ESD-TR-66-358 of the AF Electronics Systems Division, Air Force Systems Command. This research was performed at the Decision Sciences Laboratory as part of Project 7682 Man-Computer Information Processing. Reproduction in whole or in part is permitted for any purpose of the U. S. Government.

A100647512

ESD-TR-66-358
ESTI FILE COPYRETURN TO
SCIENTIFIC & TECHNICAL INFORMATION DIVISION
AFSA, BUILDING 1211

mack (1962). It is not clear why no knowledge of results should produce inhibition.

Evidence has been accumulated relating the degree of motivation or activation to physiological measures, such as skin conductance and muscle potentials (Woodworth & Schlosberg, 1954, Chap. 6 and 7, pp. 133-191; Malmö, 1959). It is known that in a vigilance task, which is essentially a no knowledge of results situation, some Ss show high basal conductance levels (Ross, *et al.*, 1959; Dardano, 1962). Furthermore, higher conductance values were associated with better performance. For these Ss it is reasonable to assume that no knowledge of results may have motivational import. No data were obtained on conductance levels with knowledge of results on these tasks. Some investigations have stated a need to relate physiological data with behavioral findings if a more comprehensive theory of vigilance is desired (Jerison & Pickett, 1963).

Search of verbal reports after a vigilance task was completed suggests additional evidence of the apparent high motivation that may occur in this type of situation. In an auditory vigilance task retrospective reports were obtained to determine what listeners do, without knowledge of results, during the task (Bakan, 1963). A factor analysis of the written responses showed five factors: (I) an arousal or interest factor, (II) and (IV) Ss' evaluation of their performance, (III) a frustration factor, and (V) a motivation factor. Factors (I) and (V) seem to agree with the conductance findings mentioned and strongly suggest that some Ss are highly motivated and aroused in vigilance tasks even though no knowledge of results is given.

The purpose of the present study was to obtain reaction time data and basal conductance levels in a vigilance-type task with and without knowledge of results. For both of these treatments the physiological and the behavioral measures were related to time on task and interstimulus intervals. The method and procedures were very similar to those employed by McCormack, *et al.* (1962).

PROCEDURE

Ss were 5 female and 5 male students from local universities who were employed part time as laboratory assistants. Two additional male Ss were recruited from the laboratory staff. Their ages ranged from 20 to 36 yr., with a mean age of 23.

Ss were required, from a viewing distance of 18 in., to respond to the appearance of a 1/4-in. outlined square displayed in the center of a CRT display of a PDP-1 computer (Digital Equipment Corp.) by pressing a standard telegraph key. A small box encasing the key permitted only the button to show and was rigidly mounted to the table of the CRT display console.

The stimulus square was presented at 5 interstimulus intervals of 30, 45, 60, 75, and 90 sec. This set of 5 intervals was randomized within each of 7 blocks of trials. Each block of stimuli consisted, therefore, of 5 presentations of the square. A total of 35 presentations made up an experimental session. The stimulus square remained on the display until S pressed the response key. The total time for each experimental session was approximately 40 min. The reaction time scores were stored in the computer and were retrieved at the end of each session for future analysis. All Ss responded with the preferred hand (right).

In addition to reaction time, basal skin conductance measures were obtained. A Grass Instruments Polygraph, Model 5C, with a dc driver amplifier and a low level dc pre-amplifier, Model 5PIG, was the recording instrument. Two silver electrodes, Grass Type E1 durable disc, were taped on the dorsal and ventral sides of the middle finger of the left hand and good contact was ensured with a Bentonite electrode paste. The left hand was also taped on the table to prevent any movement artifacts in the conductance record.

Each *S* completed two experimental sessions each on a different day. In one session he was provided with knowledge of results where his reaction time in milliseconds was displayed as 1/4-in. high numerals on the CRT immediately after each response and 1/2 in. below the position of the square stimulus. In the second session, *Ss* were not provided any information concerning their performance during no knowledge of results. *Ss* were instructed to respond as rapidly as possible in both sessions. All *Ss* were told that the average reaction time in tasks of this type was around 300 msec. Six *Ss* (3 males and 3 females) received the knowledge of results condition first and the remaining *Ss* (4 males and 2 females) were given the no knowledge of results condition first. The average separation between experimental sessions for *Ss* was 4 days.

RESULTS AND DISCUSSION

Behavioral Measures

As this experiment was similar to that of McCormack, *et al.* (1962), the data were analyzed in a like manner except for variance analysis. Two curves, not shown, were plotted, depicting reaction time as a function of time blocks and interstimulus intervals. There was no evidence of any trends between reaction time and these independent variables under the no knowledge of results condition. These results are contrary to McCormack's findings that reaction time increased with time on task (time blocks) and decreased with length of interstimulus interval (McCormack, *et al.*, 1962). As these authors were primarily concerned with trends, their $AB \times S$ design (Lindquist, 1953, pp. 237-238) did not include the knowledge of results variable, i.e., no statistical comparison was made. It is not known whether the mean reaction time scores between knowledge of results and the no knowledge conditions are significantly different. An analysis of variance was performed on our data, using a four-dimensional $ABC \times S$ design in which three treatments, namely, time blocks, interstimulus intervals, and knowledge of results, were analyzed across *Ss*. Since only one term showed statistical reliability, the variance table is not presented. Knowledge of results by *Ss* ($K \times S$) was statistically significant ($F = 6.92, p < .01$). The pooled error term employed was based on the three *S*-interactions (third order) and the fourth-order term because their mean squares were of the same order of magnitude. The significance of the first-order interaction term $K \times S$, indicates that our *Ss* differentially responded to the knowledge and no knowledge events. It was decided to analyze the source of this variability.

The most likely analysis of the data was by sex because earlier McCormack (1958, 1959, 1962) reported that sex differences may have contributed to the contradictory results he obtained. However, in another study no sex differences in reaction time were obtained (McCormack, 1960). Fig. 1 illustrates mean reaction time as a function of time blocks, knowledge of results, and sex. These

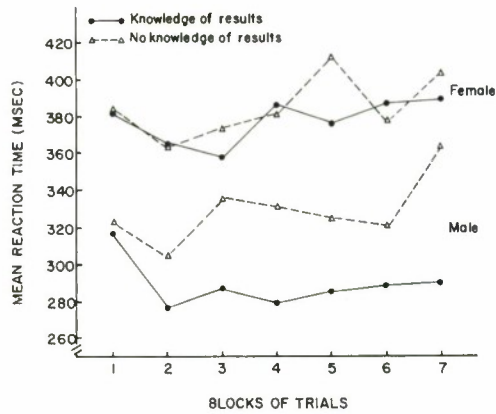


FIG. 1. Mean reaction time (msec.) as a function of time blocks, knowledge of results, and sex

curves seem to show differences in reaction time between sexes and also between knowledge and no knowledge of results for the males only. These data do not indicate any trends. Graphic analysis of interstimulus intervals (not shown) showed similar effects. Concerning sex differences, there is some evidence that this is an important factor in reaction time studies. In a simple reaction time to a light, Bellis (1932-1933) reports that females showed consistently slower reaction times than males; these were statistically significant across all six age groups from 4 to 60 yr. In accord with these results our female Ss showed slower reaction time scores than males in the no knowledge of results condition. The data were analyzed to determine whether these results were statistically reliable. As no trends were found for time blocks and interstimulus intervals, the reaction time scores for each S were pooled. Table 1 shows mean reaction time as a function of knowledge of results and sex. Variability of reaction time scores did not show heterogeneity. Males showed significantly faster reaction time scores under knowledge and no knowledge of results conditions than females. The mean differences were 78 msec. and 52 msec., respectively. For the no

TABLE 1
MEAN REACTION TIME (MSEC.) AS A FUNCTION OF
KNOWLEDGE OF RESULTS AND SEX

Sex	Knowledge of Results	No Knowledge	<i>t</i>	<i>p</i>
Males	296	333	6.09	<.01
Females	374	385	.59	n.s.
<i>t</i>	3.12	1.90*		
<i>p</i>	<.02	<.05		

*One-tailed test.

knowledge condition a one-tailed test was used based on the findings of Bellis (1932-1933). The separate analysis for males and females indicates that sex differences may account for the significant knowledge of results by Ss interaction.

It was originally felt that presence of knowledge of results should produce faster reaction time scores for males and females. To test this assumption, an analysis was performed on the data of Table 1. Only the males showed a significant mean difference. This is surprising because knowledge should provide information and have some motivational impact on all Ss. That these factors are vitiated when females respond to the task suggests that reaction time may depend on the organism. This may be interpreted that a real difference exists between the males and females, whether biological in nature and/or learned. If females are functionally dissimilar to males, then separate analyses of male and female samples in reaction time studies appears methodologically necessary. This thesis agrees with findings in cognitive task situations (Sigel, 1965).

Conductance Measures

To determine the relationship between basal skin conductance and the variables in this study the data were cast in the same form as the reaction time data as in the McCormack, *et al.* (1962) study. Fig. 2 illustrates mean basal

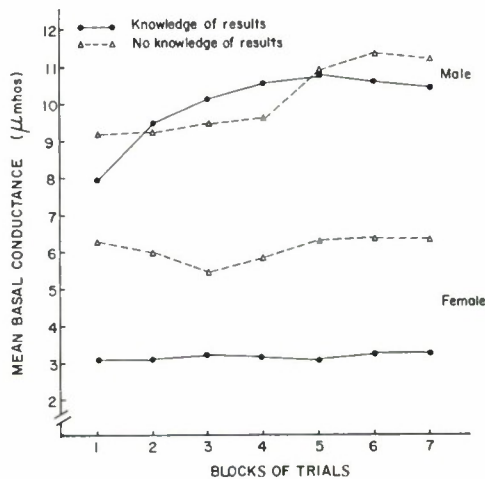


FIG. 2. Mean basal skin conductance (μmhos) as a function of time blocks, knowledge of results, and sex

conductance scores as a function of time blocks, knowledge of results, and sex. No trends are evident in the two graphs for females. The male data suggest a trend between conductance scores and blocks of trials. A sign test was used to determine whether these trends are significant (Siegel, 1956, pp. 68-75). For each male S the following test was applied to the data. If an increase in conduc-

tance occurred between two successive blocks of trials, a plus sign was recorded. If a decrease was observed, a minus sign was used, and all ties were discarded. Then a sign count was made for each *S*. The significant level of the trend was determined by performing a sign test on the pooled sign counts for each knowledge condition. A total of 42 sign counts are possible for the male data. A significant z of 2.86 ($p < .01$) was obtained for males ($n = 39$) under knowledge of results. This finding may be interpreted as follows. Under knowledge of results, the males tended to become more aroused as they proceeded to the end of the task. The slight suggestion of a trend in the male data under no knowledge of results is not a reliable one because of high variability of the scores (see Table 2). The sex differences are very pronounced and female conductance scores

TABLE 2
MEAN BASAL SKIN CONDUCTANCE (μ MHOS) AND STANDARD DEVIATIONS
AS A FUNCTION OF KNOWLEDGE OF RESULTS AND SEX

Sex		Knowledge of Results	No Knowledge	<i>t</i>	<i>p</i>
Males	<i>M</i>	10.00	10.11	.05	n.s.
	<i>SD</i>	7.45	7.84		
Females	<i>M</i>	3.18	6.05	2.16	n.s.
	<i>SD</i>	.91	2.40		
<i>t</i>		2.31	1.10		
<i>p</i>		<.05	n.s.		

for knowledge of results appears to be different from those in the no knowledge condition. To determine whether there were significant differences in the levels of the conductance scores the data were pooled across time blocks and inter-stimulus intervals. Table 2 shows the mean conductance scores and standard deviations of the pooled data. Examination of the mean data for males shows no significant differences for knowledge versus no knowledge of results. The level is of the order of 10 μ mhos suggesting a high level of arousal. The means of the female *Ss* do not show any real differences for the same conditions. Their level is about 4.6 μ mhos. The graphic analysis in Fig. 2 suggests that the females had significantly lower conductance scores than the males. To test this idea, a comparison of the sexes under knowledge and no knowledge conditions was made. Under knowledge of results the mean for females is significantly lower than for the males. Not only is there a significant mean difference, but also there is a significant difference between the groups in variability. An *F* ratio of 66.4 was obtained ($p < .01$). Continuing the variability analysis, the males showed significantly greater variability than females under no knowledge of results. An *F* ratio of 10.70 was obtained ($p < .05$). If an increase in variability means high arousal or alertness (Freeman, 1940), then these results may be interpreted as follows. The males under knowledge and no knowledge of results were more aroused or motivated than the females. The females under no

knowledge showed significantly greater variability than under knowledge of results. An F ratio of 6.89 ($p < .05$) was obtained. This finding suggests that lack of information tended to arouse them. On the basis of these analyses of conductance scores and variability, it is concluded that a high degree of arousal or motivation takes place under no knowledge of results for males and females. However, males show greater arousal than females in terms of variability under this condition.

Conductance and Reaction Time

Because sex and knowledge of results interact, it is necessary to analyze the relationship between the behavioral and physiological measures specifically for each sex and knowledge condition. When knowledge of results are presented to Ss, high conductance was related to fast reaction time (males) whereas low conductance was related to slow reaction time (females). However, there was no systematic decrease in reaction time (males) across blocks of trials concomitant with their conductance scores. Reaction time scores were low and were consistently maintained at such a level. Whether this is a function of the high level of conductance or the increasing changes in conductance (greater arousal) is not shown. In any case, high conductance as an index of high arousal appears to be associated with good performance. Low conductance appears to be associated with poor performance. The female Ss may have been content to work at a certain level and not become aroused by their poor performance levels even though they were told that the average response for persons at their age level is approximately 300 msec. Under no knowledge of results the females still showed poor performance (i.e., slow reaction times) and their conductance levels were low, indicating low arousal. However, the lack of information may have aroused them as the variability of their conductance scores increased relative to the variance in the knowledge condition. Perhaps these females were apathetic to reaction time experiments.

Another interesting finding concerning the male Ss is the relationship between their reaction times and their arousal levels during no knowledge of results. They showed high mean conductance and faster mean reaction time than the females but slower reaction time than they did under knowledge of results. This latter point means that lack of information may have been responsible for their slower reaction time scores. The high mean conductance for males without knowledge of results indicates that this situation is not one of low motivation or an inhibition state. Thus, our results are contrary to the inhibition-motivation theory of McCormack (1962) and agree with the findings of Ross, *et al.* (1959) and Dardano (1962).

REFERENCES

- BAKAN, P. An analysis of retrospective reports following an auditory vigilance task. In D. N. Buckner & J. J. McGrath (Eds.), *Vigilance: a symposium*. N. Y.: McGraw-Hill, 1963. Pp. 88-101.

- BELLIS, C. J. Reaction time and chronological age. *Soc. Exp. Biol. Med. Proc.*, 1932-1933, 30, 801-803.
- DARDANO, J. F. Relationships of intermittent noise, intersignal interval, and skin conductance to vigilance behavior. *J. appl. Psychol.*, 1962, 46, 106-114.
- FREEMAN, G. L. The relationship between performance level and bodily activity level. *J. exp. Psychol.*, 1940, 26, 602-608.
- JERISON, H. J., & PICKETT, R. M. Vigilance: a review and re-evaluation. *Hum. Factors*, 1963, 5, 211-238.
- LINDQUIST, E. F. *Design and analysis of experiments in psychology and education*. Boston: Houghton Mifflin, 1953.
- MACKWORTH, N. H. Researches on the measurement of human performance. *Med. Res. Council. Special Report No. 268*. London: H. M. Stationery Office, 1950.
- MALMO, R. B. Activation: a neuropsychological dimension. *Psychol. Rev.*, 1959, 66, 367-386.
- MCCORMACK, P. D. Performance in a vigilance task as a function of interstimulus interval and interpolated rest. *Canad. J. Psychol.*, 1958, 12, 242-246.
- MCCORMACK, P. D. Performance in a vigilance task with and without knowledge of results. *Canad. J. Psychol.*, 1959, 13, 68-71.
- MCCORMACK, P. D. Performance in a vigilance task as a function of length of interstimulus interval. *Canad. J. Psychol.*, 1960, 14, 265-268.
- MCCORMACK, P. D. A two-factor theory of vigilance. *Brit. J. Psychol.*, 1962, 53, 357-363.
- MCCORMACK, P. D., BINDING, F. R. S., & CHYLINSKI, J. Effects on reaction-time of knowledge of results of performance. *Percept. mot. Skills*, 1962, 14, 367-372.
- ROSS, S., DARDANO, J., & HACKMAN, R. C. Conductance levels during vigilance task performance. *J. appl. Psychol.*, 1959, 43, 65-69.
- SIEGEL, S. *Nonparametric statistics*. New York: McGraw-Hill, 1956.
- SIGEL, I. E. Rationale for separate analyses of male and female samples on cognitive tasks. *Psychol. Rec.*, 1965, 15, 369-376.
- WIENER, E. L. Knowledge of results in a monitoring task. *USAF AMRL-TDR-62-82*, 1962.
- WOODWORTH, R. S., & SCHLOSBERG, H. *Experimental psychology*. (Rev. ed.) New York: Holt, 1954.

Accepted November 14, 1966.